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THOUGHTS *on* MAGNETISM. *By* RICHARD KIRWAN, *Eſq*; *L.L.D. F.R.S. and M.R.I.A.*

1. THERE are two ways of explaining a natural phænomenon; the firſt, is by diſcovering the conditions and circumſtances of its production and the laws by which its action is governed; the ſecond, is by ſhewing its analogy, ſimilarity or coincidence with ſome general fact with whoſe laws and exiſtence we are already acquainted; this laſt mode is by far the moſt perfect and ſatisfactory. In the firſt ſenſe of the word electricity and magnetiſm have been in ſome meaſure explained, but in the laſt ſenſe neither; the primary cauſe of magnetiſm in particular has hitherto been ſuppoſed to relate to iron alone, or its ores, and to ſtand unconnected with all other natural phænomena. Read March 19, 1796.

2. IF therefore any other general fact or power can be diſcovered to which it bears ſome analogy or ſimilarity, it may ſo far be ſaid to be explained. Now ſuch fact or power I think may be aſſigned, namely, the power of *cryſtalization.*

3. By cryſtalization I underſtand that power by which the integrant particles of any ſolid poſſeſſing ſufficient liberty of motion unite to each other, not indiſcriminately and confuſedly, but according to a peculiar uniform arrangement, ſo as to exhibit in its laſt and moſt perfect ſtage regular and determinate forms.

4. This power is now known to be poſſeſſed by all ſolid mineral ſubſtances.

5. The forms which cryſtals, even of homogeneous ſubſtances, exhibit, are often very numerous; however in moſt caſes they may be reduced to a few primordial forms, which, as Abbé Hauy has lately experimentally proved, are derived from certain original forms appertaining to the minuteſt particles of their concretion.

6. The aſſemblage of theſe ultimate particles into viſible aggregates, ſimilarly arranged, neceſſarily requires that one of their ſurfaces ſhould be attractive of that particular ſurface of the other, which preſents a correſponding angle, and repulſive of that which preſents a different angle, otherwiſe the various regular rhomboidal and other polygon priſms and pyramids, which cryſtals preſent us, could never exiſt; conſequently the minuteſt priſm, being once formed, could never be prolonged if one end of ſuch priſms were not attractive, and the other repulſive of the ſame given ſurface.

7. Hence it has been obſerved that cryſtalization never takes place in the middle of any ſolution, but always begins at the ſurface

face or on the bottom or ſides of the veſſels that contain it, for the particles in the middle of the ſolution being confuſedly mixed with each other, and exerting their repulſive as freely as their attractive powers, the one conſtantly counteracting the other, no ſenſible accretion of a regular kind could take place, whereas the repulſive power of the uppermoſt particles, or of thoſe that reſt on the ſides or bottom of the veſſel, is reſtrained and impeded.

8. THE repulſive power of cryſtalizing ſubſtances alſo appears in many other inſtances (of the attractive no doubt has ever been formed.) Thus if ſaturate ſolutions of nitre, common ſalt, and tartar vitriolate be mixed and ſet to cryſtalize, each will cryſtalize a part, which could not happen if the particles of each of theſe ſalts did not only attract their ſimilar homogeneous, but alſo repel thoſe of a different ſpecies, otherwiſe the mere caſual circumſtance of greater proximity to one than to the other would impel them to unite indiſcriminately. Again, if a ſaturate ſolution of allum be mixed with a turbid mixture of clay, and abandoned to inſenſible evaporation, after ſome time the clay will ſubſide and form a dry maſs, but in the interior of this maſs large regular cryſtals of allum will be found, whoſe component particles muſt, to reunite, have diſplaced and repelled the particles of clay with which they were ſurrounded.

9. IF to a ſaturate ſolution of a ſalt that difficultly cryſtalizes, a cryſtal of a ſalt of the ſame ſpecies be inſerted, the whole ſolution will ſoon be brought to cryſtalize, as the cryſtal inſerted

attracts the particles diſſolved, by its different ſurfaces; but if a ſalt of a different nature be inſerted this will not happen, cryſtalization will not be promoted.

10. If to a ſolution of 2 parts nitre, and 3 parts Glauber's ſalt in 5 parts water, a cryſtal of nitre be inſerted, the nitre alone will cryſtalize; or if inſtead of nitre a cryſtal of Glauber be inſerted into it, the Glauber alone will cryſtalize. Do not theſe experiments fully evince both the attractive and repulſive powers, not only of different ſalts but of different ſurfaces of the ſame ſalt?

11. These powers within their proper ſphere of action have been found indefinitely great; thus water confined in cannon ſeveral inches thick, and expoſed to a degree of cold much beneath the freezing point, has been obſerved to cryſtalize into ice that burſt the metallic impediment oppoſed to the form it then aſſumes.

12. The vaſt difference however attending the developement of theſe two powers (of magnetiſm and cryſtalization) will undoubtedly ſtrike many as an inſuperable objection to their identity, yet their *direction* in all its varieties being exactly the ſame, difference in other circumſtances ſeems to me to indicate rather a variety of *degrees*, in the ſame power, than any eſſential difference in the powers themſelves.

I NOW come to the application of the above principles to the magnetic phænomena. Theſe may in general be reduced to the following, viz. *Attraction*, *Repulſion*, *Polarity*.

Communication.

Declination.

Inclination.

Excluſive appropriation to Iron.

Deſtruction of the Magnetic power.

1ſt, *Attraction*, *Repulſion*, *Polarity*.

THE quantity of iron found on and within ſuch parts of the ſurface of the globe as we are acquainted with, far ſurpaſſes that of any other mineral ſubſtance ſingly taken, or even of many of them taken together; ſcarce any ſtone or metallic ore or earth is found free from it; it enters into their compoſition in the proportion of from 2 to 18 or 20 per cent. and perhaps at a medium we may ſtate it in all of them at 6 per cent.; moreover its own ores are of all others the moſt common and the moſt copious; in many places, particularly in the moſt northern climates, whole mountains of it are found, and many of them magnetic. When to this conſideration we add that of the ſpecific gravity of the globe, which has been found to be 4,5 times heavier than water, notwithſtanding the immenſe quantity of water that covers the greater part of its ſurface to conſiderable unknown depths, and notwithſtanding

notwithſtanding that the ſpecific gravity of by far the greater part of the ſtones and earths it contains does not exceed and ſcarcely amounts even to three times the weight of an equal bulk of water, and that the quantity of mineral ſubſtances whoſe ſpecific weight exceeds four times that of water is almoſt infinitely ſmall in compariſon to the other known component parts of the globe, and finally that the weight of moſt iron ores is about four or five times that of water; all this I ſay conſidered, it is difficult to avoid concluding that the interior part of the globe conſiſts chiefly of iron ore diſpoſed in one or more aggregate maſſes; a concluſion that is farther confirmed, on reflecting that volcanic lavas ejected from the deepeſt receſſes with which we are acquainted contain from 15 to 20 or 25 per cent. of iron in the ſtate moſt favourable to magnetic attraction.

Taking then this aſſertion to be as fully proved as its ſubject matter is capable of being aſcertained, we may deduce from it the following corollaries:

1ſt. That as the ferruginous matter in the globe being by far the moſt copious, its univerſal attractive power is principally ſeated in the ferruginous part.

2d. That as all terraqueous matter was originally in a ſoft ſtate, its parts were at liberty to arrange themſelves according to the laws of their mutual attraction, and in fact did coaleſce and cryſtalize

cryſtalize in the direction in which they were leaſt impeded by the rotatory motion of the globe, namely in that which extends from North to South, and principally and moſt perfectly in the parts leaſt agitated by that motion, namely thoſe next the centre.

3d. THAT this cryſtalization like that of ſalts might have taken place in one or more ſeparate *ſhoots*, or as we may here call them, immenſe ſeparate maſſes, each having its poles diſtinct from thoſe of the other, thoſe in the ſame direction repulſive of and diſtant from each other.

IN conſequence then of the univerſal law of attraction of the particles of matter to each other, theſe internal magnets exert a *double* power of attraction; the firſt and moſt general, on the particles of *all* bodies indiſcriminately in proportion to their denſity, and the direct or inverſe ratio of the ſquares of their diſtances according as thoſe bodies are found within or without the earth's ſurface; and the ſecond, on bodies of their own ſpecies in proportion to their homogenity, and to the correſpondence of the arrangement of their integrant particles with that of the integrant particles of theſe internal magnets.

A MAGNET therefore is a maſs of iron, or of iron ore, whoſe oxygenation does not exceed 20 per cent. or thereabouts, whoſe particles are arranged in a direction ſimilar to that of the great internal central magnets of the globe. This I call the *magnetic arrangement.*

THE particles of iron attract each other more forcibly than thoſe of any other known ſubſtance. This appears by its coheſion, hardneſs, elaſticity and infuſibility, in each of which properties, or at leaſt in the combination of moſt of them, it exceeds all other known bodies.

HENCE a magnet *attracts iron* when within the ſphere of its action, by forcing, in virtue of its attractive power, a certain proportion of its integrant particles into a diſpoſition and arrangement ſimilar to that of its own. For in this caſe it exerts a double attractive power, that of the particles of iron to each other, which we have ſeen to be the greateſt of all others, and that of cryſtalizing bodies, which we have alſo ſeen to be indefinitely great.

THE cryſtalizing power being at once attractive and *repulſive*, according to the direction of the ſurfaces, (No. 6.) hence we ſee that one part or end of the magnet muſt repel that which the other has attracted, as long as the ſame diſpoſition of parts remains.

THE diſpoſition of parts in a particular magnet, being ſimilar to that which obtains in the great internal general magnet, extends in the direction of from North to South. Hence magnets, when at liberty to move with a certain degree of freedom, and iron, when a ſufficient number of its particles are arranged in that

that direction, and has ſufficient liberty to conform to it, points to thoſe poles. Hence this property is called *Polarity.*

THE magnetic power is greater or leſſer according to the number and homogenity of the particles *ſimilarly* and *magnetically* arranged. Hence ſmall magnets may be more powerful than a larger, and hence a magnet will attract a magnetized needle at a greater diſtance than one not magnetized.

THE magnetic power decreaſes in a certain ratio of the diſtance of the particles that exerciſe it. Hence it is ſtrongeſt in the point of contact, and at the poles, as it is there moſt *unſaturated*, and weakeſt in the central part, which ſeparates the two oppoſite poles.

WHEN a magnet is broken into ſmall pieces its power is nearly deſtroyed, becauſe though the poles ſhould be all of the ſame kind, yet the diſtance of each from the oppoſite pole is ſo ſmall that their powers counteract and conſequently deſtroy each other.

IF when a needle is attracted by the ſouth pole of a magnet a bar of iron be placed on the north pole, the needle is ſtill more ſtrongly attracted, becauſe the iron acquires alſo a ſouth pole, whoſe force is joined to that of the magnet.

IF two needles be ſuſpended from any given pole of a magnet they will diverge, becauſe they both acquire the ſame polar arrangement. If a bar of iron be laid on that pole of the magnet the divergence will diminiſh, becauſe the next end of the iron will acquire the diſpoſition of the oppoſite pole, and conſequently counteract the repulſive power of the magnet.

A MAGNET will not tranſmit its power through a bar of iron if this be too long. Muſchenbruck limits their length to ſix feet, but this depends on the ſtrength of the magnet.

THE power of a magnet (every thing elſe being equal) depends on the *number of its ſurfaces magnetically arranged*, and the *accuracy* of that arrangement.

THE arrangement is accurate when the ſynonimous ſurfaces are exactly parallel to each other, and originally conformed to and parallel with thoſe of the great general magnet.

THE magnetic attraction is ſtrongeſt in the direction perpendicular to the magnetic ſurfaces, and weakens in proportion to the magnitude of the angle of direction with the perpendicular, and conſequently is *null* when at a right angle with it. Hence the magnetic power ſeems concentrated at the *poles*, and the lateral powers are the weakeſt, as they originate only in the oblique direction of ſurfaces, or from ſurfaces inaccurately arranged.

If the ſouth pole of a magnet be charged with filings of iron, and then approached to a bar of iron ſtanding erect, part of the filings will drop off, becauſe the poles of the ſame name, by exciting a contrary arrangement, weaken each other; but if the filings were ſuſpended from the north pole of the magnet it would take up ſtill more of the filings, as the oppoſite poles ſtrengthen each other, the uppermoſt pole of the iron in this caſe becoming magnetic by poſition.

If the ſynonimous poles of two magnets of unequal powers be approached to each other, if the powers be very unequal the ſtronger immediately deſtroys the weaker, and inducing a contrary diſpoſition attracts inſtead of repelling it; if the powers be leſs unequal it requires a longer time; ſo alſo if one be *ſofter* than the other. Even if their powers be equal, yet after ſome time the ſofter will yield to the harder. If both be equally hard they only *weaken* each other.

If a magnet be cut in two, in a direction parallel to the axis, the parts before conjoined will now repel each other, becauſe they ſtill retain two ſynonimous poles.

But if the magnet be cut in two in a direction perpendicular to the axis, the two ends before conjoined will now attract each other.

If a magnetic wire be twiſted, its powers are ſo diſordered that one ſide of the wire, in ſome places of it, will be attracted and the other ſide repelled by the ſame pole of the magnet.

The power of magnets (cæteris parib.) is in proportion to their ſurfaces or as the ſquares of their diameters.—See Hutton's Magnetiſm, p. 72.

Communication.

When iron is applied to or brought within the ſphere of activity of a particular magnet, it acquires the arrangement requiſite to form the heteronymous pole, and thus becomes itſelf in ſome degree magnetic in its whole length, if this length be not totally diſproportioned to the power of the particular magnet.

Hence the other end of ſuch bar of iron acquires the arrangement of the oppoſite pole, according to the laws of cryſtalization already laid down.

Iron becomes magnetic either by contact or proximity to a magnet, or by poſition, or by internal commotion.

If a bar of iron be placed in a vertical poſition its inſenſible fibrillæ gradually acquire the magnetic arrangement, ſo that after ſome years it becomes a complete magnet, its *loweſt* part becoming a north pole, that is, pointing when free to the north, and the *upper* a ſouth pole. In the S. hemiſphere the under end becomes a ſouth pole.

A BAR of iron not previouſly magnetic does not acquire this diſpoſition in the ſlighteſt degree while lying in a horizontal or nearly a horizontal diſpoſition, but if one end of it be raiſed it immediately acquires it in ſome degree, as appears by approaching a magnetic needle to either end, becauſe in that direction it is then expoſed to the activity of the polar ends of the great general magnet.

BUT if a bar of iron be heated, though only at one end, and while hot ſet in a vertical or nearly a vertical poſition, it will acquire the magnetic power much more readily.

So alſo if one end of a bar of iron not magnetic be ſtruck againſt the ground it will become in ſome degree magnetic, the lower end becoming a north pole, &c. and if afterwards the other end be ſtruck in the ſame manner the poles will be reverſed.

HENCE it is evident that *any motion* communicated to the integrant particles of iron placed in a proper ſituation helps them to aſſume the magnetic diſpoſition already impreſſed upon them by the great general magnet.

IF the oppoſite poles of two magnets of *equal power* be approached to each other the power of both is increaſed; and

if

if one of them be *more powerful* than the other it will increaſe the magnetic diſpoſition, and conſequently the power of the weaker.

Soft iron, as its parts are moſt eaſily moved, receives the magnetic diſpoſition moſt eaſily, *hard* iron or tempered ſteel more difficultly, and *caſt* iron, as being both hard and abounding in the heterogeneous particles, moſt difficultly and imperfectly.

WHATEVER way iron is applied to a magnet the magnetic power is diffuſed in the direction of its length. Hence it ſhould ſeem that when a bar of iron is laid on a magnet the contiguous ends of the iron become poles of the *ſame name* with thoſe of the magnet to which they are contiguous, and hence may be derived the power of *armed magnets*, for the ſurfaces of the *armour* immediately beneath thoſe of the magnet impreſs a direction oppoſite to their own on thoſe of the magnet, and conſequently rectify ſuch ſurfaces of the magnet as may have been inaccurately directed, and thus ſtrengthen it.

To communicate the magnetic power to iron by friction againſt a magnet, it is neceſſary that its pole ſhould ſlide along the magnet ſeveral times in the ſame direction, for if the directions be alternately oppoſed the powers received will ſucceſſively deſtroy each other.

A SYNONIMOUS pole is formed at the end at which the friction begins, to that of the magnet applied, and an oppoſite at that at which it terminates.

Appropriation to Iron.

It has of old been obſerved that the magnetic phænomena were peculiar to iron, and the reaſons why they are ſo have been already aſſigned, but of late ſome ſemi-metals have been obſerved to partake of theſe properties, as Nickel, Kobalt and Manganeſe; this has been thought to ariſe from a mixture of ferruginous particles from which they can be ſcarcely freed, and with reſpect to Manganeſe, and in many caſes of the others alſo, this ſeems to hold true; but with reſpect to Nickel, and in ſome inſtances of the others alſo, the magnetic properties they diſcover ſeem to me to proceed from their great attraction to iron, particularly when their particles are duly arranged, for then they are expoſed to the power of the great general magnet, which acts on them in proportion to this arrangement and their affinity to iron.

Of Inclination and Declination.

These phænomena, which are ſo different in different parts of the globe, and even in different ſeaſons and hours of the day, not being as yet noted with ſufficient certainty and preciſion, I ſhall for the preſent decline entering into their explanation.